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Development of Nutraceuticals for Management of PCOS and Iron Deficiency

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ABSTRACT
The present study was aimed at developing and evaluating nutraceutical formulations using nutrient-rich seeds, nuts, and herbal ingredients for the management of Iron Deficiency Anaemia (IDA) and Polycystic Ovary Syndrome (PCOS). Two formulations, namely multigrain Nutri-Chikki and herbal leaf/nut powders, were prepared using pumpkin seeds, flax seeds, sesame seeds, watermelon seeds, almonds, dates, spinach, moringa, wheatgrass, asparagus, and Malabar spinach. The formulations were evaluated for nutritional and physicochemical parameters including protein content, fiber estimation, fat estimation, peroxide value, swelling index, hydration capacity, moisture content, crude fiber, and ash value. Organoleptic stability studies were also carried out for 45 days. The Nutri-Chikki formulation exhibited good organoleptic characteristics with no significant changes in taste, color, aroma, and texture during storage. Protein content was confirmed by Biuret reaction. Fiber estimation showed 20% crude fiber content, while fat estimation was found to be 16.6%. The peroxide value was 5.2%, indicating acceptable oxidative stability. The herbal leaf powder demonstrated satisfactory swelling index (55.6%), swelling capacity (1.4 ml/g), and hydration capacity (2.5 g water/g powder), indicating its suitability as a nutraceutical supplement. The developed formulations were rich in iron, folic acid, antioxidants, omega-3 fatty acids, vitamins, and phytochemicals that may support the management of IDA and PCOS. The study concludes that multigrain Nutri-Chikki and herbal powders can serve as promising functional foods and nutraceutical products with potential therapeutic benefits.

Keywords
Nutraceuticals,
Functional Foods
Iron Deficiency Anaemia,
Polycystic Ovary Syndrome,
Herbal Powder,

Introduction

Nutraceuticals are products derived from food sources that provide additional health benefits beyond basic nutritional value. The term "nutraceutical" is derived from the words "nutrition" and "pharmaceutical." Nutraceuticals include herbal products, dietary supplements, functional foods, probiotics, vitamins, minerals, amino acids, and antioxidants that are used to improve health and prevent diseases [1]. In recent years, increasing awareness regarding preventive healthcare and nutritional therapy has significantly enhanced the demand for nutraceutical formulations.

Polycystic Ovary Syndrome (PCOS) is one of the most common endocrine disorders affecting women of reproductive age. It is characterized by hyperandrogenism, irregular menstrual cycles, insulin resistance, obesity, and ovarian cyst formation [20-22]. PCOS is associated with metabolic abnormalities and long-term complications such as infertility, diabetes mellitus, and cardiovascular disorders. Nutritional management plays a vital role in controlling the symptoms of PCOS through improvement of hormonal balance and insulin sensitivity. Iron Deficiency Anaemia (IDA) is a widespread nutritional disorder resulting from inadequate iron levels required for hemoglobin synthesis. It leads to fatigue, weakness, reduced immunity, and impaired cognitive function. Women are more susceptible to IDA due to menstruation, pregnancy, and dietary insufficiency. Functional foods enriched with iron, folic acid, antioxidants, and vitamins may help in preventing and managing iron deficiency.

Traditional Indian snacks such as Chikki have gained popularity due to their nutritional value, affordability, and acceptability among all age groups. Multigrain Nutri-Chikki prepared using seeds and nuts can provide proteins, dietary fiber, healthy fats, vitamins, minerals, and antioxidants in a single formulation [1,2]. Pumpkin seeds, flax seeds, sesame seeds, watermelon seeds, and almonds are excellent sources of essential nutrients and bioactive compounds.

Pumpkin seeds contribute significantly to protein and mineral content and possess antioxidant properties [4]. Flax seeds are rich in omega-3 fatty acids and lignans that support cardiovascular health and reduce inflammation [5,6]. Sesame seeds contain lignans and antioxidants that may help reduce oxidative stress and hypercholesterolemia [8]. Watermelon seeds are rich in protein, iron, zinc, magnesium, and unsaturated fatty acids [9], while almonds are excellent sources of vitamin E, dietary fiber, and healthy fats [7,10]. Dates serve as natural sweeteners and are rich in carbohydrates, minerals, and antioxidants, making them ideal ingredients for energy-rich

nutraceutical products [11]. Herbal ingredients such as spinach, moringa, wheatgrass, asparagus, and Malabar spinach contain iron, folic acid, chlorophyll, vitamins, and antioxidants that may provide therapeutic benefits in PCOS and iron deficiency. Moringa oleifera possesses anti-inflammatory, antioxidant, anti-diabetic, and hormone-regulating activities [14-19,23-25]. Wheatgrass is rich in vitamins A, B, C, E, and K and exhibits antioxidant and detoxifying properties [12]. Spinach and Malabar spinach are excellent sources of iron and folic acid, while asparagus is traditionally used in Ayurvedic medicine for female reproductive health [13]. The present investigation was therefore undertaken to formulate and evaluate multigrain Nutri-Chikki and herbal powder formulations enriched with bioactive ingredients for potential application in the management of Iron Deficiency Anaemia and Polycystic Ovary Syndrome.

Materials and Methods

Materials

The ingredients used in the preparation of Nutri-Chikki included pumpkin seeds, sesame seeds, watermelon seeds, flax seeds, almonds, fresh dates, and dry dates. Herbal powders were prepared using spinach leaves, asparagus, Malabar spinach, moringa leaves, and wheatgrass. All raw materials were procured from local organic stores in Hyderabad.

Preparation of Multigrain Nutri-Chikki

Selection and Processing of Materials

The finest quality raw materials were selected and cleaned to remove impurities. The ingredients were weighed according to the formulation requirements.

Roasting of Seeds

Pumpkin seeds, sesame seeds, flax seeds, watermelon seeds, and almonds were dry roasted separately to reduce moisture content and enhance flavor.

Preparation of Fresh Date Nutri-Chikki

Fresh dates were ground into a smooth paste. Roasted and chopped seeds and nuts were mixed thoroughly with the date paste. The mixture was transferred into a tray coated with ghee and pressed uniformly. The prepared sheet was cut into desired shapes after cooling.

Preparation of Dry Date Nutri-Chikki

Dry dates were chopped, roasted, and powdered. The powder was mixed with roasted and powdered ingredients uniformly to obtain the final formulation.

Storage: Prepared Nutri-Chikki formulations were stored in airtight containers to prevent moisture absorption and oxidative deterioration.

Preparation of Herbal Leaf Powder

Fresh leaves of spinach, moringa, asparagus, wheatgrass, and Malabar spinach were washed thoroughly and shade dried. The dried materials were powdered separately and sieved to obtain fine powders. The powders were mixed uniformly according to formulation requirements and stored in airtight containers.

Evaluation Parameters for Nutri-Chikki

1. Organoleptic Evaluation

The prepared formulations were evaluated for taste, colour, aroma, and texture over a storage period of 45 days.

2. Fiber Estimation

Two grams of moisture-free and fat-free sample were digested with 200 ml of 1.25% sulfuric acid under boiling conditions for 30 minutes. The contents were filtered and washed with distilled water. The residue was treated with 1.25% sodium hydroxide solution and boiled again for 30 minutes. The residue was dried, ignited in a muffle furnace, and the loss in weight represented crude fiber content.

3. Protein Estimation

Protein estimation was carried out using Biuret reagent. The sample solution was treated with Biuret reagent, and the appearance of violet or purple colour indicated the presence of proteins.

4. Fat Estimation

Fat content was determined using Soxhlet extraction method with petroleum ether as solvent. The extracted fat was dried and weighed, and fat percentage was calculated.

5. Peroxide Value

Peroxide value was determined by reaction of extracted oil with potassium iodide followed by titration with sodium thiosulfate solution.

The peroxide value was calculated using the formula:

$$PV = (Vs - Vb) \times N \times 1000 / W$$

Where:

- Vs = Volume of sodium thiosulfate used for sample titration
- Vb = Volume used for blank titration
- N = Normality of sodium thiosulfate
- W = Weight of sample

6. Carbohydrate Determination

Carbohydrate content was determined by difference method using the formula:

Carbohydrate (%) = 100 − (Moisture % + Ash % + Protein % + Fat % + Crude Fiber %)

7. Calorific Value

The calorific value was calculated using standard conversion factors:

- Fat = 9 kcal/g
- Protein = 4 kcal/g
- Carbohydrate = 4 kcal/g

Evaluation Parameters for Herbal Powder

1. Bulk Density

Bulk density was determined by filling 50 g of powder into a graduated cylinder and tapping gently. Bulk density was expressed as weight per unit volume.

2. Hydration Capacity and Hydration Index

Fifty grams of herbal powder were soaked in water overnight. Hydration capacity and hydration index were calculated based on weight gain after soaking.

3. Swelling Capacity and Swelling Index

Three grams of herbal powder were soaked in distilled water, and volume changes were measured after standing.

4. Moisture Content

Moisture content was determined by drying samples in a hot air oven at 100°C until constant weight.

5. Crude Fiber Estimation

Crude fiber estimation was performed using acid and alkali digestion methods followed by ignition in a muffle furnace.

6. Ash Value

Total ash, acid-insoluble ash, and water-soluble ash values were determined by incineration and subsequent acid or water treatment.

Results and Discussion

Organoleptic Evaluation of Nutri-Chikki

The prepared multigrain Nutri-Chikki formulation was evaluated for organoleptic characteristics such as taste, colour, aroma, and texture over a storage period of 45 days. The formulation exhibited a sweet and nutty taste with a golden-brown appearance and crunchy texture. No significant changes were observed in sensory parameters throughout the study period, indicating good product stability and consumer acceptability.

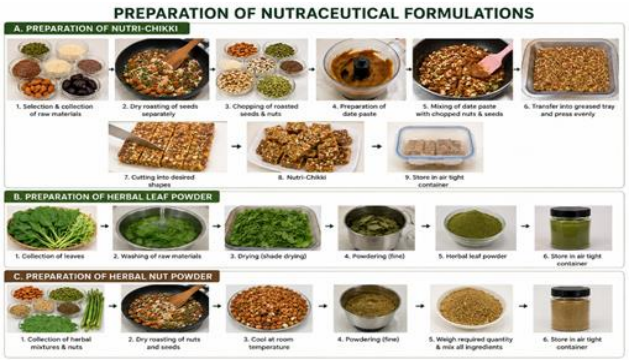
PREPARATION OF NUTRACEUTICAL FORMULATIONS
A. PREPARATION OF NUTRI-CHIKKI
B. PREPARATION OF HERBAL LEAF POWDER
C. PREPARATION OF HERBAL NUT POWDER

Table 1: Organoleptic Evaluation of Nutri-Chikki

Organoleptic Parameters	Initial Observation	Day 14	Day 28	Day 45
Taste	Sweet and nutty	No change	No change	No change
Colour	Golden brown	No change	No change	No change
Aroma	Nutty and sweet aroma	No change	No change	No change
Texture	Crunchy/Chewy	No change	No change	No change

The stability observed during storage may be attributed to the low moisture content and antioxidant-rich ingredients such as flax seeds, almonds, sesame seeds, and dates. These ingredients may help retard oxidative deterioration and maintain product quality.

Nutritional Evaluation of Nutri-Chikki

The nutritional parameters evaluated included protein content, crude fiber content, fat estimation, and peroxide value.

Table 2: Nutritional Evaluation of Nutri-Chikki

Test	Observation
Protein Content	Violet/Purple colour observed
Fiber Estimation	20%
Fat Estimation	16.6%
Peroxide Value	5.2%

Protein Estimation

Protein estimation using the Biuret test produced a violet or purple colour, confirming the presence of proteins in the Nutri-Chikki formulation. The protein content mainly originated from pumpkin seeds, watermelon seeds, almonds, sesame seeds, and flax seeds, all of which are rich sources of plant proteins. Adequate protein intake is essential for tissue repair, enzyme synthesis, and overall metabolic functions.

Fiber Estimation

The crude fiber content of the formulation was found to be 20%, indicating that the Nutri-Chikki is a rich source of dietary fiber. Dietary fiber plays a crucial role in improving digestion, promoting satiety, regulating blood glucose levels, and reducing cholesterol levels. Fiber-rich foods are particularly beneficial for women with PCOS as they may help improve insulin sensitivity and weight management.

Fat Estimation

The fat content was found to be 16.6%, which mainly consisted of healthy unsaturated fats contributed by flax seeds, sesame seeds, almonds, and watermelon seeds. These healthy fats provide energy and may help improve cardiovascular health. Omega-3 fatty acids present in flax seeds are also known to possess anti-inflammatory properties and may help in hormonal regulation.

Peroxide Value

The peroxide value of the Nutri-Chikki formulation was determined to be 5.2%, indicating acceptable oxidative stability of the formulation. A lower peroxide value suggests minimal lipid oxidation and good shelf stability during storage. The presence of natural antioxidants in almonds, sesame seeds, and dates may have contributed to reduced rancidity.

Organoleptic Evaluation of Herbal Leaf Powder

The herbal leaf powder formulation was evaluated for sensory characteristics over a 45-day storage period. The powder showed a pleasant aroma, fine texture, and green colour, which remained unchanged during storage.

Table 3: Organoleptic Evaluation of Herbal Leaf Powder

Organoleptic Parameters	Initial Observation	Day 14	Day 28	Day 45
Taste	Bitter to tangy	No change	No change	No change
Colour	Green	No change	No change	No change
Aroma	Pleasant and strong	No change	No change	No change
Texture	Fine and smooth	No change	No change	No change

The stable organoleptic properties suggest that the herbal powder formulation possesses acceptable storage characteristics when preserved in airtight containers.

Evaluation of Herbal Leaf Powder

The herbal leaf powder was further evaluated for swelling index, swelling capacity, and hydration capacity.

Table 4: Evaluation of Herbal Leaf Powder

Test	Observation
Swelling Index	55.6%
Swelling Capacity	1.4 ml/g
Hydration Capacity	2.5 g water/g powder

Swelling Index and Swelling Capacity

The swelling index of 55.6% and swelling capacity of 1.4 ml/g indicated good water absorption and expansion properties of the herbal powder. These properties are important for improving digestibility and gastrointestinal function. The fiber and polysaccharide content of spinach, moringa, and wheatgrass may contribute to the swelling behavior of the formulation.

Hydration Capacity

The hydration capacity of 2.5 g water/g powder demonstrated the ability of the powder to absorb and retain water effectively. Good hydration properties may improve palatability, texture, and bioavailability of nutrients when consumed as a dietary supplement.

Organoleptic Evaluation of Herbal Nut Powder

The herbal nut powder formulation was evaluated for taste, colour, aroma, and texture during storage studies.

Table 5: Organoleptic Evaluation of Herbal Nut Powder

Organoleptic Parameters	Initial Observation	Day 14	Day 28	Day 45
Taste	Palatable/Sweet	No change	No change	No change
Colour	Light brown	No change	No change	No change
Aroma	Pleasant aroma	No change	No change	No change
Texture	Smooth and even	No change	No change	No change

The formulation exhibited good sensory acceptability and remained stable throughout the storage period. The pleasant taste and aroma may improve consumer compliance and acceptability as a nutraceutical supplement.

Discussion

The present study successfully formulated nutritionally enriched nutraceutical products using bioactive-rich seeds, nuts, and herbal ingredients. The developed formulations demonstrated satisfactory nutritional quality, physicochemical stability, and organoleptic acceptability. Seeds such as pumpkin, flax, sesame, and watermelon are rich in proteins, minerals, antioxidants, and healthy fatty acids. Pumpkin seeds contain iron, magnesium, zinc, and proteins that may help improve hemoglobin levels and immune function. Flax seeds provide omega-3 fatty acids and lignans that possess anti-inflammatory and cardioprotective effects. Sesame seeds are rich in lignans and antioxidants that may reduce oxidative stress, while almonds contribute vitamin E and healthy monounsaturated fats.

The herbal ingredients incorporated into the formulations also possess important therapeutic benefits. Moringa oleifera is known for its antioxidant, anti-inflammatory, antidiabetic, and hormone-regulating activities, which may help in managing PCOS symptoms. Wheatgrass and spinach are rich sources of iron, folic acid, chlorophyll, and vitamins that support hematopoiesis and may aid in the prevention of iron deficiency anaemia [14–19, 23–25].

The acceptable peroxide value and absence of organoleptic deterioration during storage indicate good shelf stability of the formulations. The presence of natural antioxidants in the ingredients likely contributed to reduced oxidative degradation. Overall, the developed formulations may serve as effective functional foods and nutraceutical supplements for improving nutritional status and supporting the management of Iron Deficiency Anaemia and Polycystic Ovary Syndrome.

The present study focused on the formulation and evaluation of nutraceutical products, namely multigrain Nutri-Chikki and herbal powder formulations, for the management of Iron Deficiency Anaemia (IDA) and Polycystic Ovary Syndrome (PCOS). The formulations were prepared using nutrient-rich seeds, nuts, dates, and herbal ingredients such as pumpkin seeds, flax seeds, sesame seeds, watermelon seeds, almonds, moringa, spinach, wheatgrass, asparagus, and Malabar spinach.

The prepared formulations were evaluated for organoleptic characteristics, nutritional composition, and physicochemical properties. Nutri-Chikki showed good sensory acceptability, positive protein content, 20% crude fiber, 16.6% fat content, and acceptable peroxide value. The herbal powder formulations exhibited satisfactory swelling index, swelling capacity, and hydration capacity. Stability studies demonstrated no significant changes in sensory properties during storage.

The formulations were found to be rich in iron, antioxidants, vitamins, minerals, dietary fiber, and bioactive compounds that may support the management of IDA and PCOS.

Conclusion

The present investigation successfully demonstrated the development of nutritionally enriched Nutri-Chikki and herbal powder formulations with potential nutraceutical benefits for Iron Deficiency Anaemia and Polycystic Ovary Syndrome. The incorporation of functional ingredients such as seeds, nuts, and medicinal herbs enhanced the nutritional and therapeutic value of the formulations. The products exhibited good stability, sensory acceptability, and nutritional quality, indicating their suitability as functional foods [20-25]. The study suggests that these nutraceutical formulations may serve as convenient, affordable, and health-promoting dietary supplements, particularly for women affected by iron deficiency and hormonal disorders. Further clinical and pharmacological studies are recommended to validate their therapeutic efficacy.

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Conflict of Interests

The authors declare no conflict of interest

Ethics Approval: Not applicable

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AI Tool Declaration

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

Data Availability

Data will be available on request

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